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Survey of the Benthic Invertebrates Collected from the United States 2800 Meter Radioactive Waste Disposal Site in the Atlantic Ocean

California State Univ., Long Beach
Dept. of Biology

Prepared for

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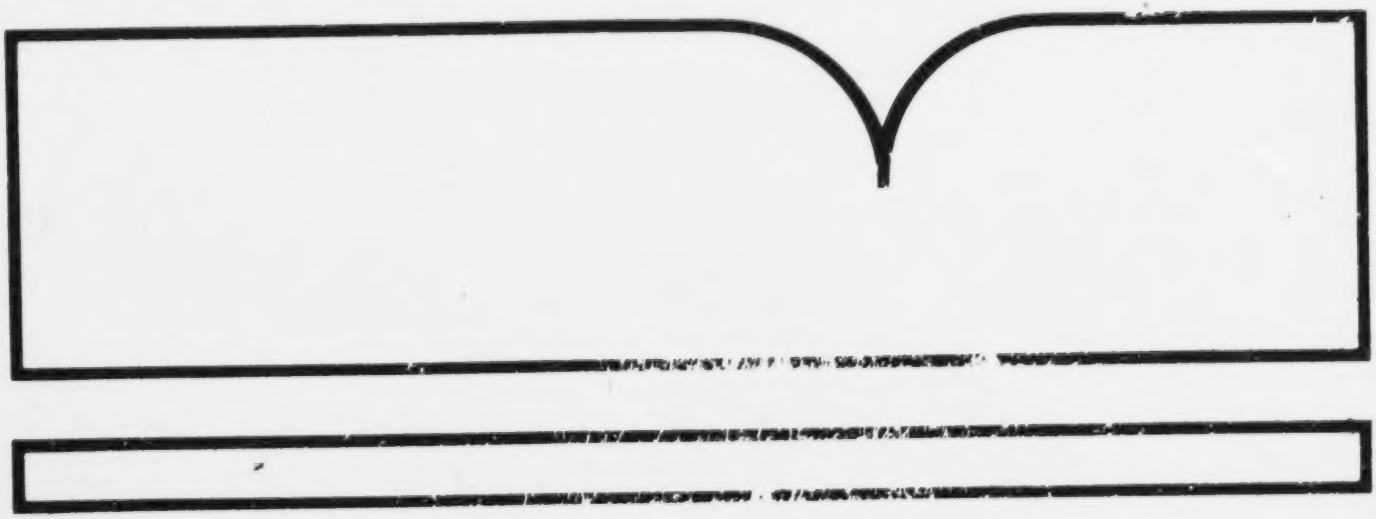

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16. ABSTRACT

In July-August, 1976, the U.S. Environmental Protection Agency conducted a survey of the Atlantic low-level radioactive waste disposal site located approximately 120 miles off the Maryland-Delaware coast at a depth of 2800 meters. Nine box core samples were collected from the dumpsite area and each was subsampled to examine the invertebrate infauna. A total of eighty-six invertebrate species were identified from a total of 353 specimens; only three of the species were previously unknown off the Atlantic coast from depths greater than 1000 meters. Approximately 50% of both the number of species and specimens were polychaetes, a figure which excluded the nematods. A total of 39 species of planktonic and 45 species of benthonic foraminifera were identified from the nine box cores plus four tube cores, the latter having been collected by the manned submersible ALVIN. A discussion of the influence of the polychaetes on possible bioturbation of the dumpsite sediments is provided, and a comparison is made with bioturbation potential by polychaetes in sediment at a low level radioactive waste dumpsite in the Pacific Ocean.

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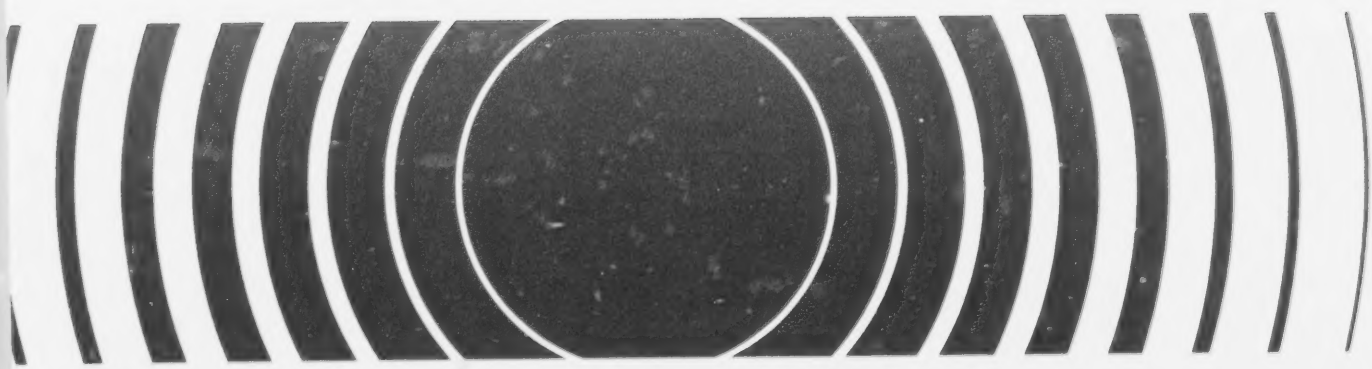

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SURVEY OF THE BENTHIC INVERTEBRATES COLLECTED FROM THE UNITED STATES 2800 METER RADIOACTIVE WASTE DISPOSAL SITE IN THE ATLANTIC OCEAN

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WASHINGTON, D.C. 20460

Foreword

The Environmental Protection Agency (EPA) was given a Congressional mandate to develop criteria, standards, and regulations governing the ocean disposal of all forms of wastes pursuant to Public Law 92-532, the Marine Protection, Research and Sanctuaries Act. Within this congressional mandate, EPA has initiated a specific program to develop regulations and criteria to control the ocean disposal of radioactive wastes.

The EPA Office of Radiation Programs (ORP) initiated feasibility studies to determine whether current technologies could be applied toward determining the fate of radioactive wastes dumped in the past. After successfully locating radioactive waste disposal containers in the disused dumpsites, ORP developed a program of site-characterization studies to investigate (a) the biological, geochemical and physical characteristics of these sites, (b) the presence and distribution of radionuclides within these sites, and (c) the performance of past packaging techniques and materials.

These studies have provided needed information and data on the past radioactive waste disposal activities concomitant with the growing national and international interest in the possible long-term effects of this low-level waste disposal option.

A key concern of EPA's ocean disposal evaluation program for low-level radioactive waste is the potential for both mobilization

and biological transport of released radionuclides from a dumpsite to man. Infaunal organisms, i.e. organisms living within the sediment, may be an important element of both of these deep-sea processes. The present report describes the marine infauna inhabiting the 2800m dumpsite, with a specific focus on the group of infaunal organisms most prevalent at the site, the polychaetous annelid worms.

The agency invites all readers of this report to send any comments or suggestions to Mr. David E. Janes, Director, Analysis and Support Division, Office of Radiation Programs (ANR-461), Washington, D.C. 20460.

Glen L. Sjoblom

Glen L. Sjoblom, Director
Office of Radiation Programs

Abstract

Quantitative benthic samples, to collect invertebrates and foraminifera, were taken in the summer of 1976 in the Atlantic Ocean 2800m radioactive waste disposal site. Nine samples were taken for invertebrates with a box core, seven of which were located within the disposal site. A total of 86 species were identified from a total of 353 specimens. Polychaetes constituted approximately 50% of both the number of species and specimens. The benthic fauna was similar at all stations, with the polychaetes Exogone dispar, Langerhansia anoculata and Prionospio steenstrupi the most frequently encountered species. A possible new species of serpulid polychaete was taken from the surface of the radioactive waste barrel which had been recovered from the dumpsite for materials analysis. All polychaetes were minute in size, and there was no visual evidence of any large scale bioturbation. Based on the minimal amount of downward movement of sediments, it seems unlikely that any significant amount of released radioactive material would become entrapped in the sediment by biological activity.

A total of 39 species of planktonic and 45 species of benthonic foraminifera were identified from 13 cores taken at the Atlantic Ocean site. Unfortunately, the rose bengal solution was extracted during the processing of samples, which made it impossible to determine live-dead ratios. As many as 11 species of foraminifera may represent undescribed forms.

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Acknowledgments

My interest and involvement in determining what organisms were present in the United States radioactive waste dumpsites and their possible role in movement of sediment began with contacts with Mr. Robert Dyer, U.S. Environmental Protection Agency, Office of Radiation Programs, and Mr. Sam Kelly, Interstate Electronics Corporation. I would like to express my thanks to these two scientists for involving me in this problem unique to the twentieth century.

I would like to thank the crew of the R/V Cape Henlopen for their assistance in obtaining the biological samples. The scientific staff of R/V Cape Henlopen, headed by Dr. Stephen Dexter, and the visiting scientists assisted me in many ways in the collection and processing of the biological samples. My thanks are especially given to Mr. Andrew Soutar, Scripps Institute of Oceanography, and Mrs. Linda Graham and Mrs. Pamela Polloni of the Woods Hole Oceanographic Institution.

I wish to acknowledge the help of the following biologists for identifying some of the organisms collected. These include: Dr. Paul Fritts, California State University, Long Beach, Foraminifera; Mr. Bruce Benedict, Marine Biological Consultants, Inc., Crustacea; Mr. Brad L. Myers, Southern California Coastal Water Research Project, Ostracod crustaceans; and Mr. Charles A. Phillips, California State University, Long Beach, Mollusca.

I. INTRODUCTION

The purpose of this investigation was to determine the benthic fauna present in and near the vicinity of the United States Atlantic deepwater radioactive waste disposal site. Emphasis was placed on the polychaetous annelids because of their abundance and their role in the movement of sediments. In addition, the foraminifera were identified, counted, and the percent of aberrant forms recorded. The role of the benthic fauna to other forms of animal life, especially fish, as it relates to possible contamination from the radioactive waste material was determined and described.

II. MATERIALS AND METHODS

Collections were made from the R/V Cape Henlopen by the author on July 31 through August 5, 1976 during the expedition of July 27 through August 6, 1976. The station locations, depths, and method of collection are given in Table 1 and Figure 1. A total of nine benthic samples were taken with a Soutar box core which sampled a surface area of approximately 930 cm^2 to a variable depth of 50-80 cm. The amount of material available for biological collection varied depending upon the needs of other investigators. For most samples only about 450-500 cm^2 of the surface area was made available for biological analyses.

Two 2.54 cm cores were taken out of the undisturbed sample to a depth of about 7-10 cm. The top 5 cm was then placed within a 1% rose bengal-70% ethanol solution for later foraminifera

analysis. These samples were later turned over to Dr. Paul Fritts for identification of foraminifera. The samples for foraminifera were dried, weighed and a 100 gram subsample taken. The sediment was then boiled with trisodium phosphate to break up the sediments (unfortunately most of the rose bengal stain was also removed), then washed through a 0.127 mm sieve. The material retained on the sieve was examined under a dissecting microscope. The foraminifera were removed for identification.

In most instances only the top 12-15 cm of sediment was processed for macroscopic animals, by washing through a 0.5 mm sieve. A sediment color change from tan to gray occurred at about a depth of 12-15 cm which presumably represented approximately that amount of sediment which had accumulated since the last glacial age. No forms of macroscopic benthic life were present below this depth. Only sample #4 was made completely available for biological analysis. This sample was placed within a bucket and a stream of sea water from a hose added; the bucket was tilted so that the overflow passed onto the sieve. Material larger than 0.5 mm was retained on the sieve and preserved with 40% formalin.

The biological material was transported to Long Beach, California on August 6, 1976 and washed again on a 0.25 mm sieve to remove any remaining fine sediment and formalin. The samples were then preserved in ethanol for later sorting and identification.

Samples for possible biological material were taken from the surface of the barrel raised from the dumpsite on July 31, 1976. The sediment was preserved with 40% formalin. All sieving of these sediments was done in Long Beach; no macroscopic animal life

was present in any of this material. Several small serpulid polychaete specimens, which possess a white calcareous tube, were collected from the surface of the barrel and preserved (see Columbo, et al., 1982, Figure 52, along lower margin of figure).

III. RESULTS

A. Invertebrates

The biological data obtained from the nine benthic samples are summarized in Tables 2-6. Tables 2 and 3 record the species of macroinvertebrates and foraminifera, respectively. Tables 4 and 5 record the number of species and specimens of macroinvertebrates and foraminifera, respectively.

A total of 86 invertebrate taxa were identified of which 39 species were polychaetes, 34 were crustaceans, 7 were mollusks, 3 were echinoderms, and the remainder consisted of nematods, sipunculids, and possibly a pogonophoran (Table 2). A total of 353 specimens were encountered of which 160 specimens were polychaetes, 100 were crustaceans, 20 were mollusks, and the remaining 73 specimens belonged to the nematods, echinoderms, sipunculids, and possibly the pogonophorans. In terms of number of specimens present, the benthos can be characterized by three species of polychaetes: Exogone dispar (Figure 2), Langerhansia anoculata (Figure 3), and Prionospio steenstrupi (Figure 4). Each of these species was present at 8 of the 9 stations sampled with the Soutar box corer. In spite of their widespread occurrence, the population of these three species averaged only four specimens or less per sample. Crustaceans, especially tanaids, and brittle stars were often seen on the surface of the sediment in the box

core, but their occurrence was limited to about 1 or 2 specimens per sample.

Two of the nine box core samples, #6 and #8, were taken outside the radioactive waste dumpsite. No differences were noted between these two samples and the other seven samples collected within the dumpsite. However, many species were present only once or twice indicating a diverse fauna but not a rich one in number of specimens.

B. Foraminifera

A total of 39 planktonic species and 45 benthonic species of forams were identified from the 13 stations in the Atlantic survey. There were 11 additional benthonic species which were identified only to genus since they could not be assigned to any known species (Table 5). A total of 95 planktonic and benthonic species were encountered from these 13 stations, of which upwards to 11 may represent new species (Table 3). Those species of benthonic foraminifera which could not be assigned to any previously known species include: Alabamina sp., Ammodiscoides sp., Cassidulina sp., Cibicides sp., Cibicidoides sp., Epistominella sp., Lagena sp., Rhabdammina sp., Sigmoilina sp., Uvigerina sp., and Virgulina sp.. Additional study is necessary to determine whether or not any or all of these represent new species. The foraminiferal fauna of the 13 stations, including the four ALVIN submersible dive stations, is fairly uniform and the composition of the benthonic population at this 2800m dumpsite is very similar to one described by LeRoy and Hodgkinson (1975) from a sample taken in the Gulf of Mexico at a depth of 1067 meters. Many of the benthonic species

identified in the present study are in close agreement with those reported by Brady (1884) from samples taken from bathyal depths on the voyage of the H.M.S. Challenger during the years 1873-1876.

Three planktonic species, Globigerina bulloides, G. falconensis, and Turborotalia inflata were present at all 13 stations. Turborotalia inflata and Neogloboquadrina pachyderma were numerically the most abundant planktonic species collected.

Numerically, the number of specimens of benthonic forms were not as numerous as the planktonic species. Bulimina auriculata was the only benthonic species taken from all 13 samples. Rhabdammina abyssorum and Hoeglundina elegans were the most abundant benthonic species.

No difference was noted between the species composition taken within and outside the radioactive waste dumpsite. A few aberrant specimens of forams were noted both within and external to the dump site but they were of the type and percent occurrence (1%) of that which is observed from other populations of either recent or fossil collections. Aberrant foraminifera occur in all populations including fossil ones. When they occur, they generally have atypical shaped chambers. The cause of aberrant forms is unknown (Dr. Paul Fritts, personal communication).

IV. DISCUSSION

Approximately 45 percent of the invertebrate species encountered in the Atlantic Ocean dumpsite were polychaetous annelids. The majority of these specimens were small and were not seen until after examination under the dissecting microscope. The worm tubes were also minute and no burrows of any type were seen

in the sediments during the processing period on board ship. The only invertebrate species noted on board ship were the brittle stars, tanaid crabs, isopods, a sea cucumber (holothurian), and a sea urchin. Jumars (1981) noted that the deep-sea benthic community is numerically dominated by small polychaetes and nematods which are a few millimeters or less in length, and by foraminiferans.

The population of invertebrates averaged about 420 specimens/m^2 or about 400/m^2 if nematods are excluded. Comparative quantitative data for bathyal depths are limited. Jumars and Hessler (1976) reported populations of 1272 specimens/m^2 from collections made in the Aleutian Trench, at a depth of 7000-7500 m. Polychaetes comprised about 49% of the specimens encountered, a figure which excluded the nematods. Since nematods are considered as meiofauna, they are generally excluded from population analysis of macrofauna. In the present study, the polychaetes constituted 50% of the total specimens collected, a figure which excluded the 30 specimens of nematods.

Most of the species of polychaetes encountered are either detrital feeders or substrate engulfers. The detrital feeders, such as Prionospio steenstrupi, utilize palps or other appendages to bring material from the substratum surface to their mouths (see Fig. 4). All syllids are provided with an eversible proboscis; benthic species are probably elective deposit feeders and thus feed on the surface of the sediment. Many polychaetes engulf the particle, reject the particle or, in some species, incorporate the particle into their tube.

Substratum engulfers such as Tharyx marioni, function in much the same manner as earthworms do on land, that is, by taking in sediment into their digestive system, digesting at least some of the contained organic material, and egesting the remaining material out their anus, usually at the sediment surface. Organisms with such a type of feeding behavior may play a role in the upward transport of sediments in the form of fecal pellets. The population of polychaetes was sparse and the size of the specimens was small at this dumpsite which indicates that biological movement of sediments (bioturbation) either upward or downward may be minimal. Further evidence for the potential lack of sediment movement was the sharp change in sediment color at 12-15 cm, a depth easily reached by organisms at other localities. Furthermore, microscopic evidence failed to reveal any positively identifiable fecal pellets. Obviously these animals were feeding, but because their size was minute their fecal pellets were correspondingly small, suggesting minimal vertical sediment transport potential. This lack of sediment bioturbation in the Atlantic Ocean dumpsite would indicate that any radioactive leakage from the barrels would tend to stay on the surface of the sediment (or be transported away by currents) and would not be buried, if only the bioturbation action of infauna is considered. With the exeption of fish and an occasional sea urchin observed by personnel within the deep submersible Alvin, no specimens present within the sediments had a large enough biomass to permit radioactivity analysis.

Biological conditions were strikedly different at the Pacific Ocean dumpsite (Reish, in press). Many large sediment tubes and large fecal pellets were present indicating a rich biological area. In fact, the majority of the material retained on the 0.5 mm sieve was fecal pellets from polychaetes. This evidence for sediment bioturbation indicated that sediment transport is active and that any leakage of radioactive materials would, in part, be moved vertically. Furthermore, the Pacific Ocean dumpsite would be a prime site for collection of benthic animals for analysis of heavy metals and/or their radioactive counterparts because of the larger sized animals and greater population levels.

The role of polychaetes in the marine food chain is relatively well known in shallow waters but little studied in the deep sea. In shallow waters within the photic zone, polychaetes may be herbivores, filter feeders, detrital feeders, carnivores, or sediment engulfers. They, in turn, are fed upon by such invertebrates as other polychaetes, snails, crustaceans, and echinoderms, as well as by fish. Intertidal polychaetes are also fed upon by shore birds. Unpublished studies by the author have shown that a single fish or bird may contain over 100 specimens of polychaetes at the time of capture. Very little is actually known of the role polychaetes play in the deep sea. We can assume that species related to shallow water forms have similar feeding habits. The specific food habits of deep sea polychaetes have not been investigated but gut contents of large specimens have been examined to a

limited extent. In most instances they have fed on the sediment and digested what organic material it contained. What feeds upon these polychaetes is also unknown. It is likely that fish feed upon these worms but deep-sea fish with swim bladders usually have empty stomachs by the time they are brought to the surface since the stomach and swim bladder evert as a result of the reduced pressure. Because of the small size of the polychaetes in the Atlantic Ocean disposal site, possible movement of any radioactive waste leakage from sediments to polychaete to fish may be minor. However, because of the large size of polychaetes in the Pacific Ocean disposal site, there may be a significant movement of radioactive materials, in the event of a leakage, from the sediment to the polychaete to the fish. Whether or not the movement of radioactive material through deep-sea food chains will reach fish harvested by man, is difficult to say. Certainly it is more likely for the radioactive isotopes to find their way to a commercially important organism if the isotope enters into the food chain instead of being buried in sediments.

A list of the polychaetes previously known from off the east coast of the United States in depths greater than 1000 meters is given in Table 6. A total 316 different taxa have been reported of which 201 are identified to species. It is interesting to note that 97 of these species were described since 1965 by Hartman (1965) and Hartman and Fauchald (1971). Only three species from the present

collection were previously unknown off the Atlantic coast from depths greater than 1000 meters: Glycera capitata is known from shallow water off the New England coast, but it had only been reported from oceans other than the Atlantic in depths greater than 1000 meters. Myriowenia gosnoldi is only known previously from a collection off New England from 97m and off Brazil in 530m. Sternapsis fossor has been collected off the New England coast in depths up to 200m. Thanks to the papers by Hartman (1965) and Hartman and Fauchald (1971), the polychaete fauna in the deep water off the U.S. Atlantic coast seem to be fairly well characterized.

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TABLE 1

Station Locations, Atlantic Ocean Radioactive Waste Disposal Site, 1976

Station Number	Depth in Meters	Date	Latitude	Longitude	Type of Sample
1	2870	8-2-76	38°25'N	72°12'W	Box Core*
2	2830	8-2-76	38°31'N	72°11'W	Box Core
3	2880	8-3-76	38°26'N	72°08'W	Box Core
4	2880	8-3-76	38°26'N	72°03'W	Box Core
5	2840	8-3-76	38°30.5'N	72°09'W	Box Core
6	2920	8-4-76	38°23'N	72°10'W	Box Core
7	2840	8-4-76	38°28'N	72°12'W	Box Core
8	2860	8-5-76	38°31'N	72°14'W	Box Core
9	2820	8-5-76	38°33'N	72°08'W	Box Core
Barrel pickup		7-31-76	38°30.8'N	72°09.4'W	

*Box core sampler developed by Andrew Soutar, Scripps Institution of Oceanography, La Jolla, California.

TABLE 2

Systematic List of the Macroinvertebrates Collected from the Atlantic Ocean Radioactive Waste Disposal Site, 1976

Phylum Nematoda
nematodes, unidentified

Phylum Annelida
Class Polychaeta
Aglaophamus sp.
Alciope sp.
Ammotrypane abranchiata (Stop-Bowitz)
A. aulogastrella Rathke
Ammotrypanella arctica McIntosh
Amphicteis vestis Hartman
amphinomid, unidentified
Anobothrus ?gracilis (Malmgrem)
?Anobothrus sp.
Aricidea suecica Eliason
Cossura longocirrata Webster and Benedict
Ephesiella macrocirris Hartman and Fauchald
Exogone dispar (Webster)
Fauvelopsis brevis (Hartman)
Glycera capitata Orsted
goniadid fragment, unidentified
hesionid fragment, unidentified
Kesun gravieri (McIntosh)
Langerhansia anoculata Hartman and Fauchald
Leonira minor Hartman
Lumbrineris atlantica (Kinberg)
Lumbrineris sp.
Myriochele nr. heeri Malmgrem
Myriochele ?pygidialis Hartman
Myriochele sp., fragment, unidentified
Myriowenia gosnoldi Hartman
Notomastus latericeus Sars
Ophryotrocha sp.
Paraonis cornatus Hartman
P. gracilis (Tauber)
polynoid fragment, unidentified
Prionospio steenstrupi Malmgrem
Scoloplos sp.
Serpulid
Sphaerodoropsis elegans Hartman and Fauchald
Sternapsis fossor Stimpson
Tachytrypane jeffreysi McIntosh
Terebellides lobatus Hartman and Fauchald
Tharyx marioni (Saint-Joseph)
?Trichobranchus sp.

TABLE 2 (continued)

Phylum Arthropoda
Class Crustacea
Order Copepoda
copepods, unidentified
harpacticoids, unidentified
Pleuromomma borealis

Order Ostracoda
Philomedes sp.
podocopeds, unidentified

Order Isopoda
Eurycope sp.
Eurycope sp.
Hapolmesus cf. *insignis* Hansen
Hapolmesus sp.
ischnomesid, unidentified
macrostylid, unidentified
Macrostylus sp.
Macrostylus sp.
Storthyngura cf. *truncata* Richardson
Storthyngura sp.

Order Tanaidacea
Apseudes gracilis Norman and Stebbing
Neotanais micromorpher Gardiner
Neotanais sp.
neotanaid, unidentified
tanaid, unidentified

Order Cumacea
bodotriid, unidentified
?*Diastylis sp.* A
?*Diastylis sp.* B
diastylid, juveniles
Eudorella sp.
lampropids, juvenile
leuconid, juvenile
nannastracid, juvenile

Order Amphipoda
Harpinia sp.
?*Harpiniopsis sp.*
oedicerotid, juvenile
phoxocephalid, juvenile
Urothoe sp. A
?*Urothoe sp.* B

TABLE 2 (continued)

Phylum
- Class Pelecypoda
  - ?myid, unidentified
  - mytilid, unidentified
  - nuculanid, unidentified
  - nuculid, unidentified
  - pelecypod, unidentified
  - venerid, unidentified
- Class Scaphopoda
  - dentalid, unidentified

Phylum Echinodermata
- Class Ophiuroidea
  - *Aeropsis rostrata*
  - brittlestars, unidentified
- Class Holothuroidea
  - sea cucumber, unidentified

Phylum Sipunculoidea
- sipunculids, unidentified

?Phylum Pogonophora
- ?pogonophoran, unidentified

TABLE 3

Systematic List of the Foraminifera Collected From

the Atlantic Ocean Radioactive Waste Disposal Site, 1976

Aderootrema glomerata (Brady)
Alabamina sp.
Alveolophragmium scitulum (Brady)
Ammodiscoides sp.
Ammomarginulina foliaceus (Brady)
Bathysiphon rufus de Folin
Bulimina aculeata d'Orbigny
Bulimina auriculata Bailey
Bulimina marginata d'Orbigny
Bulimina striata d'Orbigny
Subsp: *mexicana* Cushman
Cassidulina sp.
Cibicides sp.
Cibicidoides cf. *C. lobatulus* (Walker and Jacob)
Cibicidoides rugosus (Phleger and Parker)
Cibicidoides sp.
Cribrostomoides nitidus (Goes)
Cribrostomoides (?) wiesneri (Parr)
Cystammina pauciloculata (Brady)
Epistominella sp.
Gaudryina atlantica? (Bailey)
Globigerina bulloides (d'Orgigny)
Globigerina falconensis Blow
Globigerinita incrusta Akers
Globigerinoides conglobatus (Brady)
Globigerinoides parkerae Bermudez
Globigerinoides ruber (d'Orbigny)
Globoquadrina dehiscens dehiscens Chapman, Parr and Collins
Globorotalia cultrata cultrata (d'Orbigny)="*G. menardii*" of Authors
Globorotalia cultrata menardii (Parker, Jones & Brady ex d'Orbigny)
Globorotalia cf. *G. scitula* (Brady)
Globorotalia truncatulinoides (d'Orbigny)
Globorotalia tumida tumida (Brady)
Glomospira charoides (Jones and Parker)
Gyroidina neosoldanii Brotzen
Hastigerina siphonifera (d'Orbigny)
Hoeglundina elegans (d'Orbigny)
Hormosina carpenteri Brady
Hormosina monile Brady
Karreriella bradyi (Cushman)

TABLE 3 (continued)

Karreriella novangliae (Cushman)
Lagena sp.
Melonis pompilioides (Fichtel & Moll)
Miliolinella subrotunda (Montagu)
Neogloboquadrina dutertrei (d'Orbigny)
Neogloboquadrina pachyderma (d'Orbigny)
Nodosaria flintii Cushman
Nonion barleeanus (Williamson)
Oolina globosa (Montagu)
Oolina hexagona (Williamson)
Orbulina universa d'Orbigny
Oridorsalis tenera (Brady)
Oridorsalis umbonatus (Reuss)
Pullenia bulloides (d'Orbigny)
Pullenia subcarinata (d'Orbigny)=*Pullenia quinqueloba* (Reuss)
Pulleniatina obliquiloculata (Parker and Jones)
Pyrgo lucernula (Schwager)
Pyrgo murrhyna
Pyrulina extensa (Cushman)
Pyrulina fusiformis (Roemer)
Reophax delicatula (Bermudez and Key)
Rhabdammina abyssorum Sars
Rhabdammina sp.
Robulus sp.
Sigmoilina sp.
Sigmoilopsis schlumbergeri (Silvestri)
Sphaeroidina bulloides d'Orbigny
Sphaeroidinellopsis subdehiscens (Blow)
Subsp: *paenedehiscens* Blow
Thurammina papillata Brady
Trochammina globigerinaformis (Parker and Jones)
Trochammina squamata Jones and Parker
Turborotalia crassiformis (Galloway and Wissler) *ronda* (Blow)
Turborotalia inflata (d'Orbigny)
Turborotalia quinqueloba (Natland)
Uvigerina peregrina
Uvigerina sp.
Vaginulina legumen (Linnaeus)
Virgulina sp.

TABLE 4

Species and Number of Macroinvertebrates Collected from the Atlantic Ocean Radioactive Disposal Site 1976

Species/Station Number:	1	2	3	4	5	6	7	8	9	Total
Nematoda, unidentified	2	5	10	4	2	3	2		2	30
Annelida - Polychaeta										
Aglaophamus sp. (acirrate)				1						1
Alciope sp.	1									1
Ammotrypane abranchiata					1	4				5
Ammotrypane aulogastrella			1							1
Ammotrypanella arctica				2						2
Amphicteis vestis			2	1			2		1	6
amphinomid, fragment	1			1						2
Anobothrus ?gracilis			2				1			3
?Anobothrus sp.				1						1
Aricidea suecica							1			1
Cossura longocirrata								1		1
Ephesiella macrocirris		1								1
Exogone dispar		1	1	2	1	1	1	1	3	11
Fauveliopsis brevis	1		1			1			1	4
Glycera capitata		2		1	2		1	1	1	8
goniadid, fragment	1									1
hesionid, fragment			2							2
Kesun gravieri					1	1				2
Langerhansia anoculata	1	4	1	7	4	1	7	4		29
Leonira minor				2		1				3
Lumbrineris atlantica	1				1					2
Lumbrineris sp.	1				2					3
Myriochele n. heeri									1	1
Myriochele ?pygidialis	1							1		2
Myriochele sp., ant. frag.							1			1
Myriowenia gosnoldi					2			1	1	4
Notomastus latericeus		2	1	2				1	2	8
Ophryotrocha sp.			1							1
Paraonis cornatus								2		2
Paraonis gracilis			1	1		1			1	4
polynoid, fragments			1	1						2
Prionospio steenstrupi		2	9	4	1	1	7	2	2	28
Scoloplos sp.				4					1	5
Sphaerodoropsis elegans				1						1
Sternapsis fossor			1							1
Tachytrypane jeffreysi									1	1
Terebellides lobatus		1							1	2
Tharyx marioni		1	2	2	1	1		1		8
?Trichobranchus sp.				1						1

TABLE 4 (continued)

Species / Station Number:	1	2	3	4	5	6	7	8	9	Total
Arthropoda - Crustacea										
Apseudes gracilis			1	1	1		3			6
bodotriidae, unidentified						1				1
copepod, unidentified		1								1
?Diastylis sp. A						4		1		5
?Diastylis sp. B						1				1
diastylidae, juvenile	1						2			3
Eudorella sp.		2								2
Eurycope sp. A			1	2		3				6
Eurycope sp.						1				1
Haplomesus cf. insignis				1						1
Haplomesus sp. A			2				1	1		4
harpacticoidea, unidentified			3		1	1				5
Harpinia sp.				2		3			1	6
?Harpiniopsis sp.		1								1
ischnomesidae, unidentified			1					1		2
isopoda, unidentified				1		1				2
lampropidae, unidentified							1	1		2
leuconidae, unidentified						1				1
Macrostylus sp. A		1	1	3	1	4	1			11
Macrostylus sp., juvenile		1	1	1	1	1	1	1		7
nannastacidae, unidentified	1		2			1				4
neotanaidae, juvenile			1						1	2
Neotanais micromorpher	1									1
Neotanais sp.				5					1	6
Oedicerotidae, juvenile			1							1
Philomedes sp.								1		1
phoxocephalidae, juvenile			4	1	1	1				7
Pleuromomma borealis								3		3
podocopids, unidentified	2	3								5
Storthyngura cf. truncata						1				1
Storthyngura sp., juvenile							1			1
tanaidacea, juvenile						2				2
?Urothoe sp. B						1				1
Urothoe sp.					1					1
Mollusca - Pelecypoda										
?myid, unidentified	2	1		2	1	1				7
mytilidae, unidentified			1	2		1				4
nuculanidae, unidentified				1						1
nuculidae, unidentified				1						1
pelecypod, broken, unidentified			1			1				2
veneridae, unidentified		1					1			2

TABLE 4 (continued)

Species / Station Number:	1	2	3	4	5	6	7	8	9	Total
Mollusca - Scaphopoda										
dentalidae, unidentified							1	1	1	3
Echinodermata										
Aeropsis rostrata				1						1
brittlestars		2	1		4	2		3	3	15
holothuroidea					1					1
Sipunculoidea										
sipunculid, unidentified	3	9		2	1		2	4	1	22
?Pogonophora										
?pogonophoran, unidentified								2	2	4
Number of species	15	19	28	33	21	30	19	21	20	86
Number of specimens	17	41	55	64	31	47	37	34	28	353

TABLE 5

Species and Number of Foraminifera Collected from

the Atlantic Ocean Radioactive Waste Disposal Site, 1976

Species	Planktonic Benthonic	Station Number												
		1	2	3	4	5	6	7	8	9	676	677	678	680
Adercotrema glomerata	B	10	2	3	9	2	1	4		8	1	3	3	2
Alabamina sp.	B	1												
Alveolophragmium scitulum	B	1												
Ammodiscoides sp.	B							1						
Ammomarginulina foliaceus	B	1												
Bathysiphon rufus	B													5
Bulimina aculeata	B								1				1	
Bulimina auriculata	B	6	17	4	5	7	8	1	5	5	4	6	5	4
Bulimina marginata	B		3		1			1			3			
Bulimina striata	B													
Subsp: *mexicana*	B							2			1			
Cassidulina sp.	B							1			2	1		
Cibicides sp.	B							4	3		1		3	
Cibicidoides cf. *C. lobatulus*	B	6	5	6	6	3	11	10	12	3	10		5	
Cibicidoides rugosus	B			1		1	8		1			1	1	
Cibicidoides sp.	B					1	1							2
Cribrostomoides nitidus	B	2												
Cribrostomoides (?) wiesneri	B	1										2		1
Cystammina pauciloculata	B		1			3	2	2				1		
Epistominella sp.	B		1					3			4		2	
Gaudryina atlantica?	B												1	

TABLE 5 (continued)

Species	Planktonic Benthonic	Station Number 1	2	3	4	5	6	7	8	9	676	677	678	680
Globigerina bulloides	P	27	4	15		20	11	42	11	15	5	24	21	38
Globigerina falconensis	P	10	2	11		14	8	17	1	10	6	6	2	5
Globigerinita incrusta	P		3	1		7		9				11		6
Globigerinoides conglobatus	P	3	3	2								1		
Globigerinoides parkerae	P	2	1	3	2	7	1							16
Globigerinoides ruber	P	6	2	7	4	15	1	7	7	6		7	2	12
Globoquadrina dehiscens dehiscens	P											1		
Globorotalia cultrata cultrata	P	8	6	3	12	3	7	4	15	1	1		6	1
Globorotalia cultrata menardii	P	16	10	11	13	12	9	1	6		8	2	6	5
Globorotalia cf. *G. scitula*	P	1						2						
Globorotalia truncatulinoides	P	7	3	7	6	3	6	10	3			1		1
Globorotalia tumida tumida	P	5	4	6	3	1	8	1	5	6	3		9	2
Glomospira charoides	B					1							1	
Gyroidina neosoldanii	B	3	1		1			3	2				1	
Hastigerina siphonifera	P	1			4	2		1	1					1
Hoeglundina elegans	B	12	15	13		10	17	28	17	11	13	3	10	5
Hormosina carpenteria	B								1					
Hormosina monile	B						1			1				
Karreriella bradyi	B		1		1		1						1	
Karreriella novangliae	B	1			1		1	1			1			
Lagena sp.	B			1		2	1	3	1	1	1			
Melonis pompiliodes	B		5		5	2	1	8	5	3	4	2	2	
Miliolinella subrotunda	B							1						
Neogloboquadrina dutertrei	P	13	5	13		4	18	6	6	10	14	2	11	6
Neogloboquadrina pachyderma	P	16	64	72		62	17	46	35	71	237	127	43	76
Nodosaria flintii	B						2	4						

TABLE 5 (continued)

Species	Planktonic Benthonic	Station Number 1	2	3	4	5	6	7	8	9	676	677	678	680
Nonion barleeanus	B	6	4	1	4	2		1		3	3	3	1	1
Oolina globosa	B									1		1		
Oolina hexagona	B												1	
Orbulina universa	B						2	2	4		1			3
Oridorsalis tenera	P	4	1			2			1	2	6			1
Oridorsalis umbonatus	B	1	1					3	1	1			1	
Pullenia bulloides	B	2	2			1		7					1	
Pullenia subcarinata	B			1		2				2	1	1		
Pulleniatina obliquiloculata	P	2					1	1						
Pyrgo lucernula	B	7	4	2	5	9	5	13	10	4		2	9	3
Pyrgo murrhyna	B							1	1		1		1	
Pyrulina extensa	B						2					2		
Pyrulina fusiformis	B													1
Reophax delicatula	B													1
Rhabdammina abyssorum	B	3	5	2	5	7	4	6	1	9		6	8	2
Rhabdammina sp.	B	41	11	11	42	17	28	5		27	10	45	21	15
Robulus sp.	B							1						
Sigmoilina sp.	B							1			1			
Sigmoilopsis schlumbergeri	B						2							
Sphaeroidina bulloides	B	2	2	2	5	3	2	9	3	2	2	3	1	
Sphaeroidinellopsis subdehiscens	P											1		
Subsp: *paenedehiscens*	P													
Thurammina papillata	B	2	1		2	4	3	2	1	3	1			
Trochammina globigerinaformis	B			1						1		1	1	
Trochammina squamata	B			1									2	2
Turborotalis crassiformis	P	1								1			1	

TABLE 5 (continued)

Species	Planktonic Benthonic	Station Number												
		1	2	3	4	5	6	7	8	9	676	677	678	680
Turborotalia inflata	P	74	91	90	147	100	107	68	131	66	197	37	147	79
Turborotalia quinqueloba	P	4	9	10	3	5	15		6	7	4	2	7	15
Uvigerina peregrina	B	2	2	4	3		1	15	5	2	5	1	2	
Uvigerina sp.	B							1						
Vaginulina legumen	B			1									1	
Virgulina sp.	B	1										1		

TABLE 6

List of Polychaetous Annelids Reported Off the East Coast of United States from Depths Greater than 1000 Meters

Family Aphroditidae
- *Aphrodita aculeata* Linnaeus
- *Laetmonice filicornis* Kinberg
- *Laetomonice* spp.

Family Polynoidae
- *Antinoana fusca* Hartman and Fauchald
- *Eunoe nodosa* (Sars)
- *Eunoe* cf. *spinulosa* Verrill
- *Eunoe* sp.
- *Macellicephala* sp.
- harmothoids, unidentifiable
- polynoids, unidentifiable

Family Sigalionidae
- *Leanira minor* Hartman
- *Leanira* sp.
- *Pholoe anoculata* Hartman
- *Pholoe* sp.
- *Psammolyce globula* Hartman
- *Sthenelais* sp.
- *Sthenolepis tetragona* (Oersted)
- sigalionids, unidentified

Family Chrysopetalidae
- *Dysponetus gracilis* Hartman
- *?Dysponetus* sp.

Family Amphinomidae
- *Chloeia* sp.
- *Paramphinome jeffreysii* (McIntosh)
- *Pareurythoe* sp.
- amphinomids, unidentified

Family Peisidicidae
- *Peisidice bermudensis* Hartman and Fauchald

Family Pisionidae
- *Pisionura abyssorum* Hartman and Fauchald

Family Euphrosinidae
- *Euphrosine* sp.

TABLE 6 --(continued)

Family Phyllodocidae
Anaitides sp., anoculate
Anaitides groenlandica (Oersted)
Austrophyllum maculatum Hartman and Fauchald
Eulalia anoculata Hartman and Fauchald
Eulalia spp.
Notalia sp.
Paranaitis kosteriensis (Malmgren)
Paranaitis wahlbergi (Malmgren), anoculate
Pirakia lanceolata Hartman
Protomystides bidentata (Langerhans)
Pseudomystides limbata punctata Hartman
phyllodocids, unidentified

Family Alciopidae
alciopid, unidentified
Vanadis sp.

Family Lopadorrhynchidae
Lopadorrhynchus ?uncinatus Fauvel
Lopadorrhynchus sp.
Maupasis sp.
lopadorrhynchid, unidentified

Family Typhloscolecidae
?Travisiopsis lanceolata Southern
?Typhloscolex sp.
typhloscolecid, unidentified

Family Tomopteridae
Tomopteris sp.

Family Hesionidae
Hesiocaeca bermudensis Hartman
Neopodarke woodsholea Hartman
Nereimyra ?punctata (Muller)
hesionids, unidentified

Family Pilargidae
Ancistrosyllis groenlandica McIntosh
Ancistrosyllis sp.
Sigambra tentaculata (Treadwell)
Synelmis albini (Langerhans)
pilargid, unidentified

Family Syllidae
Braniella pupa Hartman
Exogone dispar (Webster)
Exogone spp.
Exogoninae, not identified
Exogonita oculata Hartman and Fauchald

TABLE 6--(continued)

Family Syllidae (continued)
Langerhansia anoculata Hartman and Fauchald
Langerhansia cornuta (Rathke)
Odontosyllis sp.
Sphaerosyllis brevifrons Webster and Benedict
Typosyllis spp.
syllids, unidentified

Family Nereidae
Ceratocephala loveni Malmgren
?Ceratocephala sp.
Ceratonereis versipedata Ehlers
Namalycastis profundus Hartman
Nereis caecoides Hartman
Nereis zonata Malmgren
Nereis sp.
Nicon sp.
Platynereis dumerilii (Audouin and Milne Edwards)
?Platynereis sp.
nereids, unidentified

Family Nephtyidae
Aglaophamus groenlandica Hartman
Aglaophamus sp., acirrate
Aglaophamus sp.
Nephtys hystricis McIntosh
Nephtys paradoxa Malm
nephtyids, not identified

Family Sphaerodoridae
Clavodorum atlanticum Hartman and Fauchald
Ephesiela macrocirris Hartman and Fauchald
Ephesiella mixta Hartman and Fauchald
Sphaerodoropsis corrugata Hartman Fauchald
Sphaerodoropsis elegans Hartman and Fauchald
Sphaerodoropsis longipalpa Hartman and Fauchald

Family Glyceridae
Glycera mimica Hartman
Glycera tesselata Grube
Glycera spp.

Family Goniadidae
Glycinde profunda Hartman and Fauchald
Goniada norvegica Oersted
Goniada sp.
Progoniada regularis Hartman and Fauchald

Family Onuphidae
Hyalinoecia sp.
Nothria iridescens (Johnson)
Nothria pallidula Hartman

TABLE 6--(continued)

Family Onuphidae (continued)
Nothria textor Hartman and Fauchald
Nothria spp.
Onuphis quadricuspis Sars
Paranothia atlantica Hartman
Paronuphis bermudensis Hartman
onuphid, not identified

Family Eunicidae
Eunice collini Augener
Eunice norvegica (Linnaeus)
Eunice sp.
eunicids, not identified

Family Lumbrineridae
Lumbrineris atlantica (Kinberg)
Lumbrineris crassicephala Hartman
Lumbrineris fragilis (Muller)
Lumbrineris latreilli Audouin
Lumbrineris paradoxa (Saint-Joseph)
Lumbrineris nr. *tenuis* (Verrill)
Lumbrineris spp.
Ninoe breviceps (McIntosh)
Ninoe dibranchiata Hartman and Fauchald
Ninoe gayheadia Hartman

Family Arabellidae
Drilonereis falcata minor Hartman
Drilonereis sp.
Haematocleptes leaenae Hartman and Fauchald

Family Dorvilleidae
Dorvillea rudolphi anoculata Hartman
Dorvillea sp.
Protodorvillea sp.
Ophryotrocha sp.
dorvilleid, unidentified

Family Orbiniidae
Califia schmetti (Pettibone)
Haploscoloplos fragilis intermedius Hartman
Haploscoloplos spp.
Microrbinia linea Hartman
Naineris quadricuspida (Fabricius)
Scoloplos spp.
orbiniids, unidentified

Family Paraonidae
Aedicira belgicae (Fauvel)
Aedicira parva Hartman and Fauchald
Aparaonis abyssalis Hartman

TABLE 6--(continued)

Family Paraonidae (continued)
Aricidea abranchiata Hartman
Aricidea neosuecica Hartman
Aricidea suecica Eliason
Aricidea tetrabranchiata Hartman and Fauchald
Aricidea spp.
Paradoneis lyra (Southern)
Paraonides monilaris Hartman and Fauchald
Paraonides rubriceps Hartman and Fauchald
Paraonis cornatus Hartman
Paraonis gracilis (Tauber)
Paraonis gracilis, aristate type
Paraonis reductus Hartman
Paraonis uncinatus Hartman
paraonids, unidentified

Family Apistobranchidae
Apistobranchus typicus (Webster and Benedict)

Family Spionidae
Laonice antarcticae Hartman
Laonice cirrata (Sars)
Laonice spp.
Polydora sp.
Prionospio cirrifera (Wiren)
Prionospio ehlersi Fauvel
Prionospio steenstrupi Malmgren
Prionospio spp.
Spiophanes kroyeri Grube
Spiophanes spp.
spionids, unidentified

Family Magelonidae
Magelona capax Hartman
Magelona spp.

Family Disomidae
Disoma watsoni Fauvel
Disoma spp.

Family Poecilochaetidae
Poecilochaetus bermudensis Hartman
Poecilochaetus fulgoris Claparede
Poecilochaetus sp.
poecilochaetid, unidentified

Family Heterospionidae
Hetrospio longissima Ehlers

Family Chaetoperidae
Phyllochaetopterus sp.
?Telepsavus sp.

TABLE 6 --(continued)

Family Cirratulidae
Chaetozone gayheadia Hartman
Chaetozone setosa Malmgren
Chaetozone ?setosa Malmgren
Tharyx annulosus Hartman
Tharyx marioni (Saint-Joseph)
Tharyx nigrorostrum Hartman and Fauchald
Tharyx spp.
cirratulids, unidentified

Family Cossuridae
Cossura longocirrata Webster and Benedict
Cossura sp.

Family Ctenodrilidae
Zeppelina prolonga

Family Flabelligeridae
Fauveliopsis brevis (Hartman)
Fauveliopsis glabra (Hartman)
Fauveliopsis scabra Hartman and Fauchald
Flabelligella minuta Hartman
Flabelligella papillata Hartman
Flabelligera sp.
Ilyphagus octobranchus Hartman
Ilyphagus sp.
flabelligerids, unidentified

Family Scalibregmidae
Ascterocheilus bergingianus Uschakov
Ascherocheilus intermedius (Saint-Joseph)
Ascherocheilus sp.
Neolipobranchus glabrus Hartman and Fauchald
Pseudoscalibregma aciculata Hartman
Pseudoscalibregma parva (Hansen)
Pseudoscalibregma sp.
Scalibregma inflata Rathke
Sclerobregma branchiata Hartman
Sclerobregmella antennata Hartman and Fauchald
Scalispinigera cirrata Hartman and Fauchald
scalibregmids, unidentified

Family Opheliidae
Ammotrypane abranchiata (Stop-Bowitz)
Ammotrypane ?aulogaster Rathke
Ammotrypane aulogastrella Hartman and Fauchald
Ammotrypane chaetifera Hartman
Ammotrypane cylindricaudatus Hansen
Ammotrypane sp.
Ammotrypanella arctica McIntosh
Kesun gravieri (McIntosh)
Ophelia profunda Hartman
Tachytrypane jeffreysii McIntosh
opheliids, unidentified

TABLE 6--(continued)

Family Sternaspidae
Sternaspis sp.

Family Capitellidae
Barantolla near *americana* Hartman
Capitella near *capitata* (Fabricius)
Capitella aberranta Hartman and Fauchald
Dasybranchus sp.
Heteromastus filiformis (Claparede)
?Leiochrides sp.
Notomastus latericeus Sars
Notomastus teres Hartman
Notomastus spp.
Pseudocapitella incerta Fauvel
capitellids, unidentified

Family Maldanidae
Asychis biceps (Sars)
?Axiothella sp.
Clymenura borealis (Arwidsson)
Clymenura cirrata (Ehlers)
?Clymenura polaris (Theel)
Clymenura sp.
Isocirrus planiceps (Sars)
Isocirrus sp.
Lumbriclymene nasuta Wesenberg-Lund
Lumbriclymene sp.
Maldane cuculligera Ehlers
Maldane sarsi Malmgren
Microchymene tricirrata Arwidsson
Nicomache lumbricalis (Fabricius)
Notoproctus abyssus Hartman and Fauchald
Notoproctus oculatus Arwidsson
Praxillella gracilis (Sars)
Praxillella praetermissa (Malmgren)
Praxillella spp.
Rhodine sp.
maldanids, unidentified

Family Oweniidae
Myriochele near *heeri* Malmgren
Myriochele ?pygidialis Hartman
Myriochele spp.
Owenia ?fusiformis delli Chiaje

Family Bogueidae
Boguella ornata Hartman and Fauchald

Family Sabellariidae
Lygdamis ?asteriformis (Augener)
Monorchos varians (Treadwell)

TABLE 6--(continued)

Family Sabellariidae (continued)
Phalacrostemma cidariophilum Marenzeller
Phalacrostemma elegans Fauvel
sabellarids, unidentified

Family Pectinariidae
pectinariids, unidentified

Family Ampharetidae
Amage spp.
Ampharete arctica Malmgren
Ampharete spp.
Amphicteis gunneri (Sars)
Amphicteis sargassoensis Hartman and Fauchald
Amphicteis trichophora Hartman
Amphicteis vestis Hartman
Amphicteis sp.
Anobothrus gracilis (Malmgren)
Auchenoplax crinita Ehlers
Olyphanostomum pallescens (Theel)
Lysippe labiata Malmgren
Melinna cristata (Sars)
Melinna sp.
Melinnata americana Hartman
Muggoides cinctus Hartman
Neopaiwa cirrata Hartman and Fauchald
Phyllampharete longicirra Hartman and Fauchald
Samytha sexcirrata (Sars)
Samythella elongata Verrill
Sosanella apalea Hartman
ampharetids, unidentified

Family Terebellidae
Laphania boecki Malmgren
Leaena minima Hartman
Leaena sp.
Leaena collaris minima Hartman
Pista? cristata (Muller)
Artacama globosa Hartman and Fauchald
Amaena trilobata (Sars)
Euthelepus abranchiatus Hartman and Fauchald
Euthelepus atlanticus Hartman and Fauchald
terebellids, unidentified

Family Trichobranchidae
Terebellides lobatus Hartman and Fauchald
Terebellides stroemii Sars
Terebellides sp.
Trichobranchus americanus Hartman
Unobranchus abyssalis Hartman
trichobranchids, unidentified

TABLE 6 --(continued)

Family Sabellidae

Chone sp.
Euchone incolor Hartman
Euchone spp.
Fabricia sabella (Ehrenberg)
Jasmineira bermudensis Hartman
Jasmineira filiformis Hartman
Jasmineira sp.
Potamethus singularis Hartman
sabellids, unidentified

Family Serpulidae

Vermiliopsis ?langerhansi Fauvel
Filogranula gracilis Langerhans
Filogranula spp.
Spirodiscus grimaldii Fauvel
serpulids, unidentified

Explanation of Figures

Figure 1. Location of box core samples within and external to the Atlantic 2800m depth radioactive wastes dumpsite boundary.

Figure 2. Anterior end of the polychaete *Exogone dispar*, redrawn after Pettibone, 1963.

Figure 3. Anterior end of the polychaete *Langerhansia anoculata*, redrawn after Hartman, 1965.

Figure 4. Anterior end of the polychaete *Prionospio steenstrupi*, redrawn after Light, 1978.

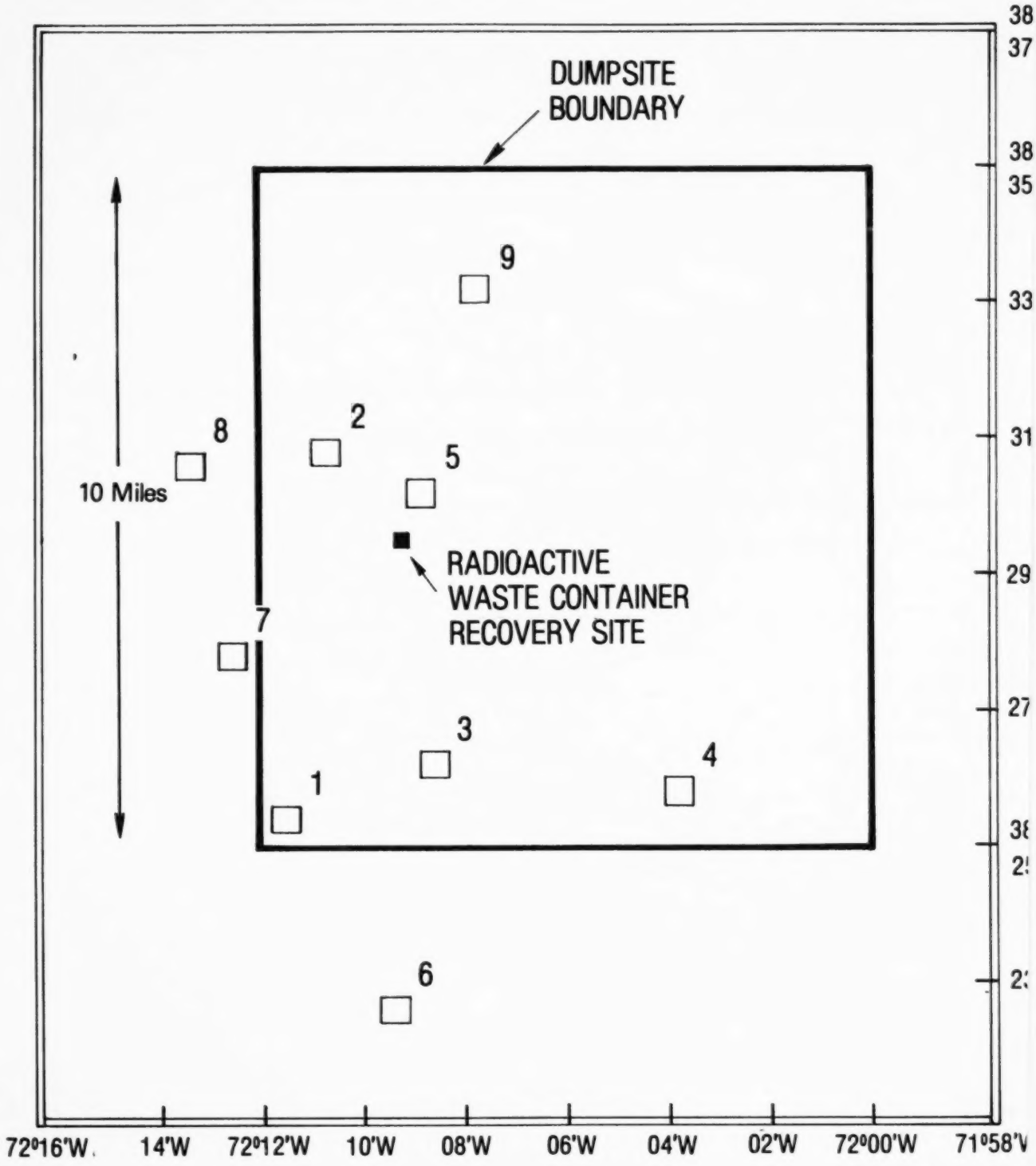

FIGURE 1. Location of Box Core Samples Within and External to the Atlantic 2800m Depth Radioactive Waste Dumpsite Boundary

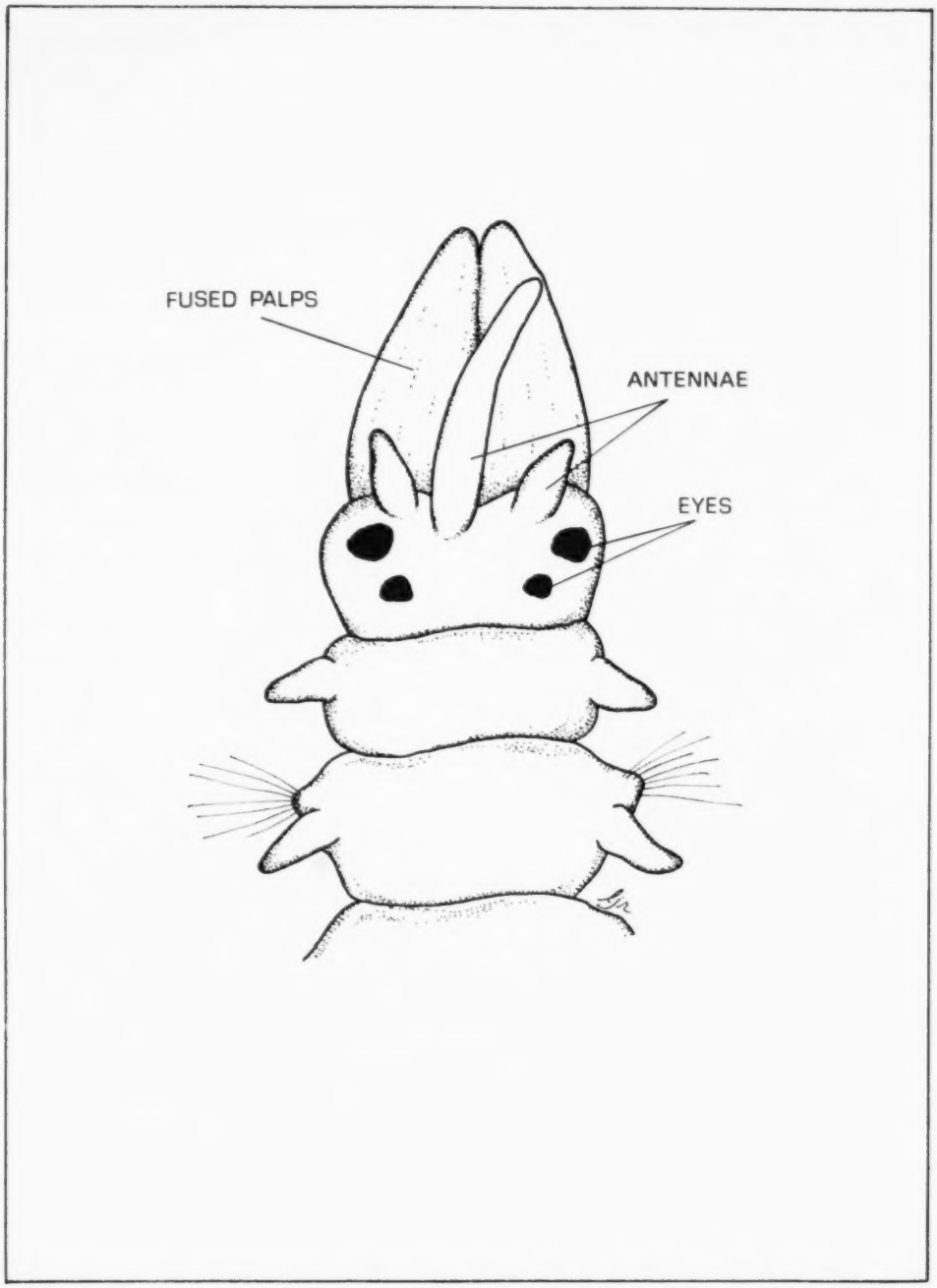

Figure 2. Anterior end of the polychaete Exogone dispar.

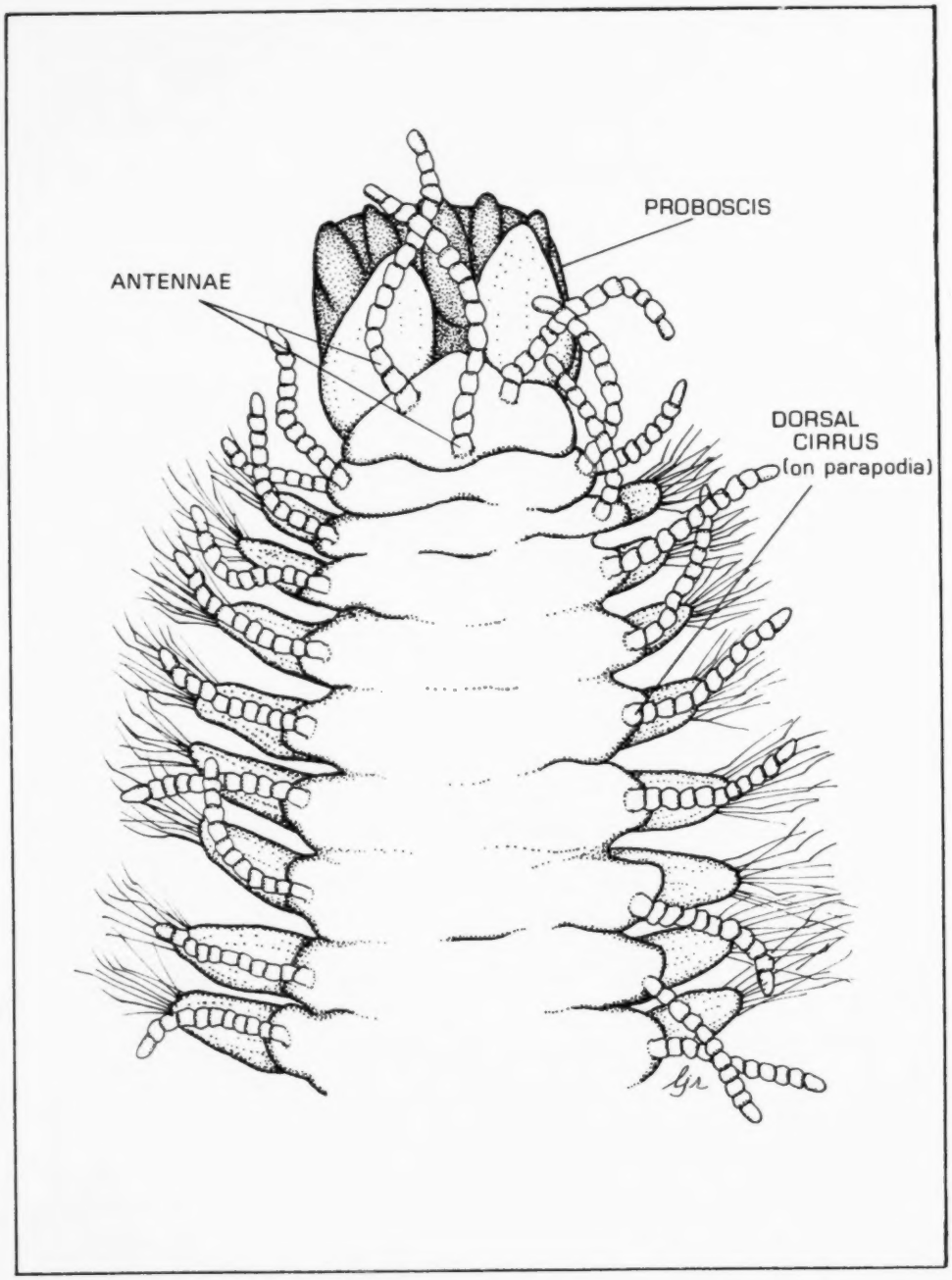

Figure 3. Anterior end of the polychaete Langerhansia anoculata.

Figure 4. Anterior end of the polychaete Prionospio steenstrupi.